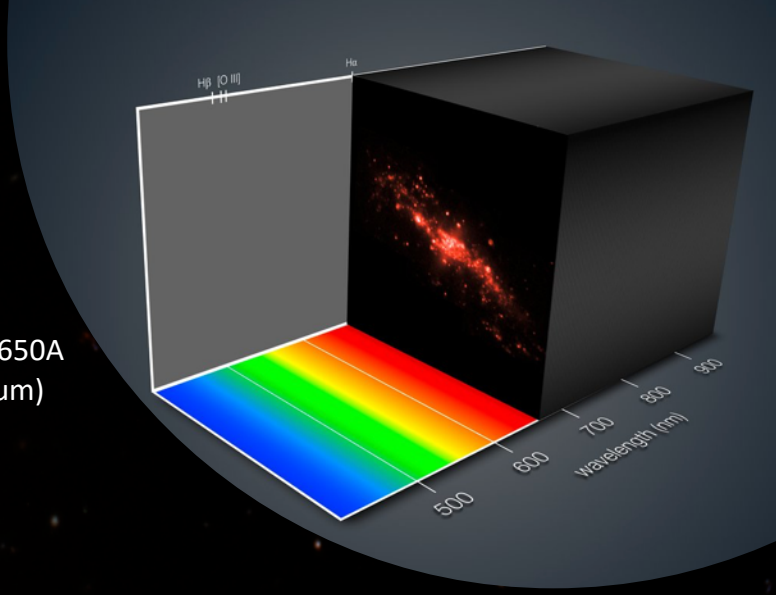
A 3D view of Galaxies in Clusters

Nicholas Amos[1,2], John Stott[1], KMOS Cluster Survey
[1] Lancaster University, UK
[2] Isaac Newton Group of Telescopes, Spain



MUSE view of NGC 4650A
(ESO/MUSE consortium)

What's an IFU?

- Mix of imaging and spectroscopy.
- You get a spectrum for each pixel in your image.
- Tells you the chemical signatures of your target per pixel.
- This can be seen in the graphic in the upper right where you get an 'image' of your target at different wavelengths.

Glossary:

IFU – Integral Field Unit.

IFS – Integral Field Spectroscopy.

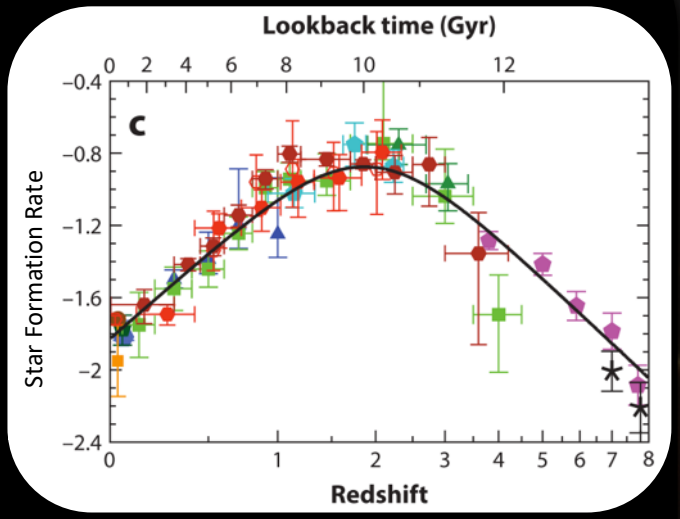
MUSE – Multi-object Spectroscopic Explorer. An IFU on the Very Large Telescope, Chile.

KMOS – K-band Multi Object Spectrograph. An IFU on the Very Large Telescope, Chile.

The KMOS instrument and its 24 IFU arms
(ESO/KMOS consortium)

Galaxies in Clusters

Field Galaxies



Modified from Madau & Dickinson, 2014

- Large data volumes across a range of distances. From, for example:
  - KROSS (Stott et al., 2016)
  - KMOS^{3D} (Wisnioski et al., 2019)

- From the plot above we see a clear reduction in star formation rate (SFR) from approximately 10 billion years ago.
- For field galaxies the reasons for this are thought to be 'secular' processes such as star formation feedback.

Modified from Peng et al., 2010

Glossary:

Secular processes – Internal processes proceeding within a galaxy with no external interference.

Star formation feedback – outflows from forming stars preventing gas from condensing into stars.

Field Galaxies – Isolated, gravitationally independent galaxies.

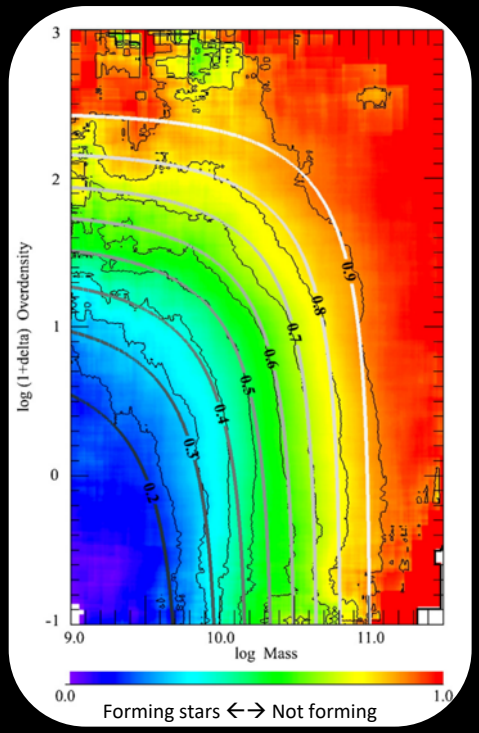
Cluster Galaxies – Groups of galaxies that gravitationally interact in a denser environment.

KROSS – KMOS Redshift One Spectroscopic Survey. A field galaxy survey using KMOS.

KCS – KMOS Cluster Survey. A galaxy cluster survey using KMOS.

K-CLASH – KMOS-CLASH survey. A survey that includes field and cluster galaxies and expands our understanding of these galaxies at approximately 2.5 – 6 billion years ago.

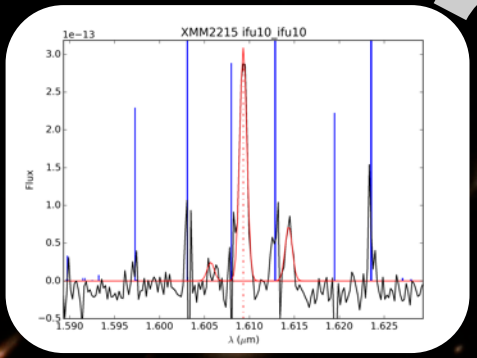
Cluster Galaxies



- Much smaller data volumes. From, for example:
  - KCS (Beifiori et al., 2017)
  - K-CLASH (Tiley et al., 2020)

- The processes we see in field galaxies are still important.
- **BUT** we also have to consider the environment these galaxies are in and their interactions with each other (Peng et al., 2010).

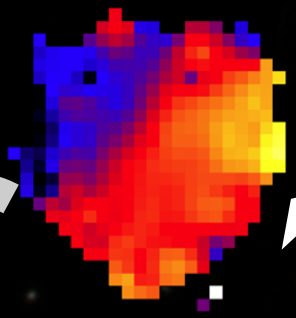
1D spectrum



How are we investigating?

2D Hα emission map

Velocity map

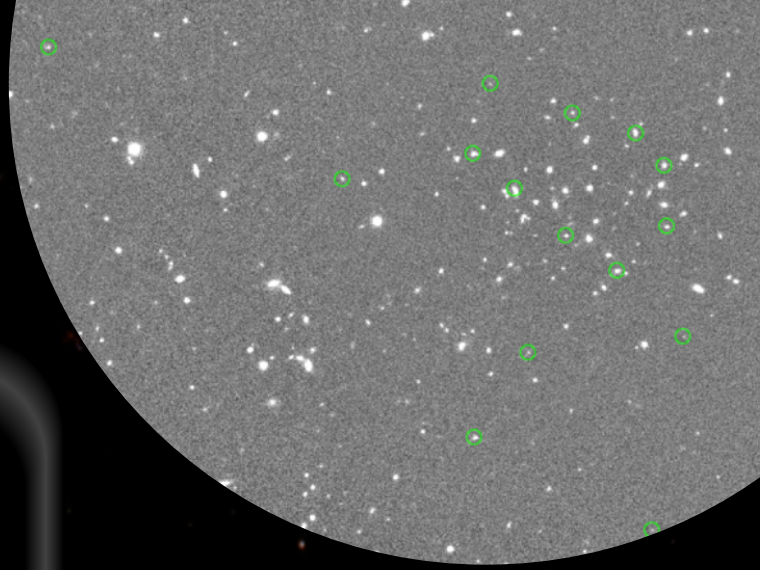


All images on this page are from Amos et al. (in prep).

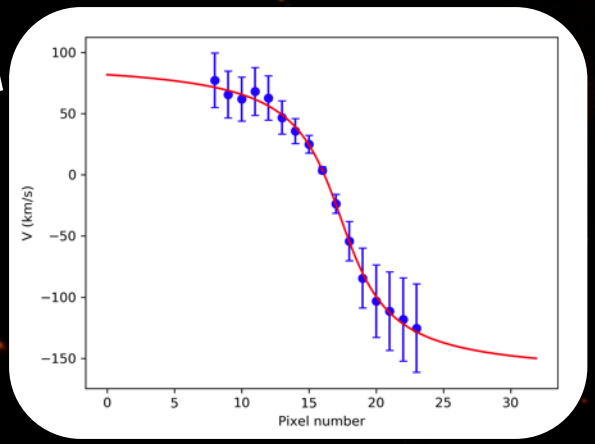
We need information on the chemical signatures and internal motions of cluster galaxies approximately 10 billion years ago to quantify these quenching mechanisms:

← KMOS data from KCS to gain the 2D information on chemical signatures (e.g. Hα tells us how many stars are being formed). This in turn allows us to study the internal motions and external interactions via velocity mapping.

→ Imaging data to assess the shape, size, and mass of the galaxies. This is also essential as it will disentangle the effects we discover in the spectroscopy data.

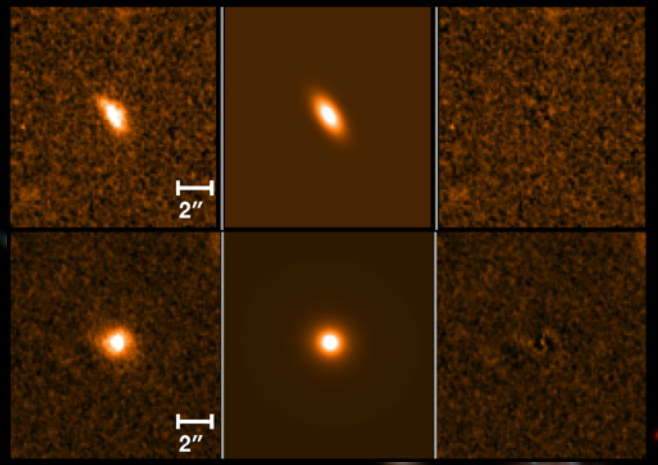


XMMXCS J2215.9-1738, taken with *Hubble Space Telescope (HST) Wide-Field-Camera 3 (WFC3)* (Targeted members of Galaxy Cluster circled in green)



1D rotational velocity model

Image Model Residuals



What next?

In order to form quantitative comparisons between field and cluster galaxies and their respective quenching mechanisms we must form models of of these galaxies.

- 2D velocity model from 1D rotation model.

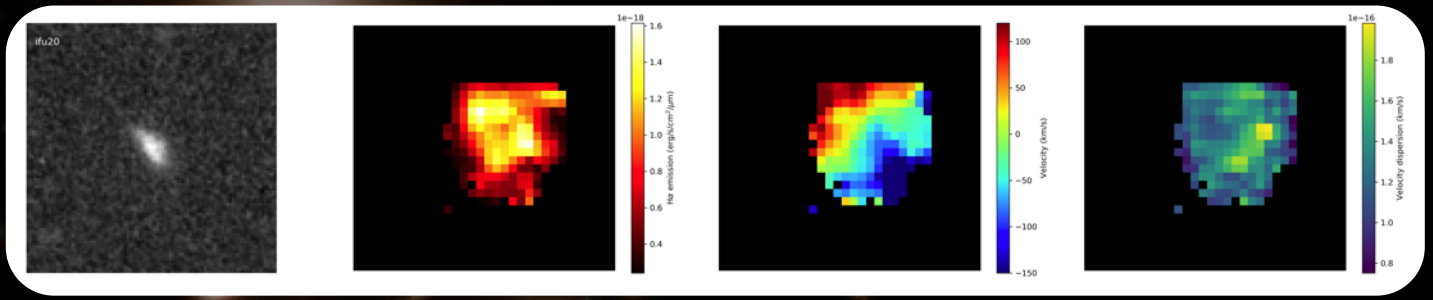
Use velocity information to obtain:
- Dark-matter content
- Motions of the galaxies within the cluster to understand their relation to their environment.

Emission line ratio maps:
- Metal content
- Active galactic nuclei content
- Impact of these on SFR.

References

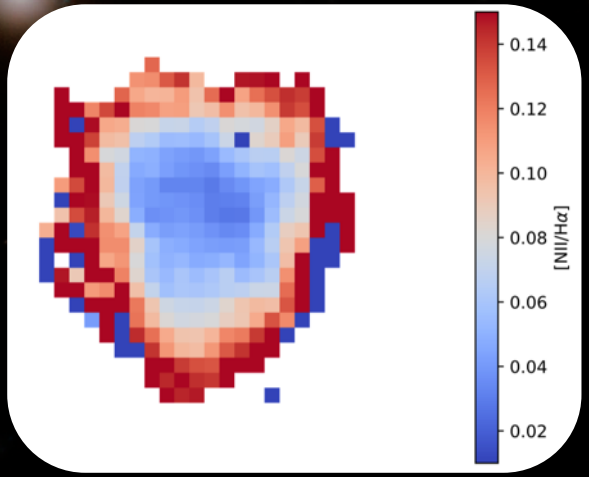
Beifiori A., et al., 2017. *MNRAS* **846** 120
Madau P. & Dickinson M., 2014. *ARA&A* **52** 415
Peng Y., et al., 2010. *ApJ* **721** 193
Tiley A., et al., 2020. *MNRAS* **496** 649
Stott J., et al., 2016. *MNRAS* **457** 1888
Wisnioski E., et al., 2019. *ApJ* **886** 124

Stellar light | Hα emission map | Velocity map | Gas content



More data ≠ More problems

More data ≡ More answers!



Early line ratio map (Amos et al., in prep)